AFRL-AFOSR-JP-TR-2016-0069

# Theoretical Framework for Interaction Game Design

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KYOTO UNIVERSITY GRADUATE SCHOOL

05/19/2016
Final Report



Air Force Research Laboratory
AF Office Of Scientific Research (AFOSR)/ IOA
Arlington, Virginia 22203
Air Force Materiel Command

# REPORT DOCUMENTATION PAGE

*Form Approved*
*OMB No. 0704-0188*



**1. REPORT DATE** *(DD-MM-YYYY)*
19-05-2016

**2. REPORT TYPE**
Final

**3. DATES COVERED** *(From - To)*
14 May 2014 to 13 May 2017

**4. TITLE AND SUBTITLE**
Theoretical Framework for Interaction Game Design

**5a. CONTRACT NUMBER**

**5b. GRANT NUMBER**
FA2386-14-1-0005

**5c. PROGRAM ELEMENT NUMBER**
61102F

**6. AUTHOR(S)**
Toyoaki Nishida

**5d. PROJECT NUMBER**

**5e. TASK NUMBER**

**5f. WORK UNIT NUMBER**

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
KYOTO UNIVERSITY GRADUATE SCHOOL
KYOTODAIGAKUKATSURA NISHIKYO-KU
KYOTO, 615-8246 JP

**8. PERFORMING ORGANIZATION REPORT NUMBER**

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**
AOARD
UNIT 45002
APO AP 96338-5002

**10. SPONSOR/MONITOR'S ACRONYM(S)**
AFRL/AFOSR IOA

**11. SPONSOR/MONITOR'S REPORT NUMBER(S)**
AFRL-AFOSR-JP-TR-2016-0069

**12. DISTRIBUTION/AVAILABILITY STATEMENT**
A DISTRIBUTION UNLIMITED: PB Public Release

**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**
The PI aimed at establishing a theoretical framework for building a common ground that may allow for content-rich, proficient and reliable communication between people and robots. To solicit high quality and spontaneous contribution from people, the PI needed to make the process of common ground acquisition as playful as possible, by incorporating aspects of game, story and play. The notion of interaction game is critical to induce a strong engagement of participants. This was addressed through learning from demonstration for acquiring interaction patterns, cognitive aspects of interaction game and an integrated framework for interaction game design. Major results encompass a robust learning algorithm from demonstration SAXImitate, an integrated toolbox MC2 (Motif Change and Causality Discovery), implementation and evaluation of a virtual basketball game, investigation of the effect of back imitation, a method for inducing intentional stance in HAI (Human-Agent Interaction), using physiological indices for discriminating intrinsic and extrinsic stress, and SES (Synthetic Evidential Study).

Project had to be cancelled a year early due to political complications. Prof Nishida collaborated with Il Hong Suh, who is also funded by AOARD under FA2386-14-1-0009

**15. SUBJECT TERMS**
Human Machine Trust

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT | b. ABSTRACT | c. THIS PAGE | | | LUTZ, BRIAN |
| Unclassified | Unclassified | Unclassified | SAR | 11 | 19b. TELEPHONE NUMBER (Include area code) 315-227-7006 |

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Final Report for AOARD Grant FA2386-14-1-0005

# Theoretical Framework for Interaction Game Design

**May 12, 2016**

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Period of Performance: May/14/2014 – May/13/2016

**Abstract:**

We aim at establishing a theoretical framework for building a common ground that may allow for content-rich, proficient and reliable communication between people and robots. To solicit high quality and spontaneous contribution from people, we need to make the process of common ground acquisition as playful as possible, by incorporating aspects of game, story and play. The notion of interaction game is critical to induce a strong engagement of participants. We addressed learning from demonstration for acquiring interaction patterns, cognitive aspects of interaction game and an integrated framework for interaction game design. Major results encompass a robust learning algorithm from demonstration SAXImitate, an integrated toolbox $MC^2$ (Motif Change and Causality Discovery), implementation and evaluation of a virtual basketball game, investigation of the effect of back imitation, a method for inducing intentional stance in HAI (Human-Agent Interaction), using physiological indices for discriminating intrinsic and extrinsic stress, and SES (Synthetic Evidential Study).

## 1. Background

In the AI era, human-AI symbiosis is among the most critical issues. The question is how to achieve it. Our hypothesis is to achieve the sharing hypothesis: the more is shared among the participants, the more empathy is gained. We believe that common ground, defined as presuppositions for conversation that each participant is supposed to share about surroundings, activities, perceptions, emotions, plans, interests, etc., is critical for establishing a fluent and reliable communication between human and robot.

Common ground is either communal, consisting of human nature, communal lexicons, and cultural facts/norms/ procedures or personal consisting of perceptual bases gestural indications, partner's activities, salient perceptual events, actional bases, and personal diaries (Clark 1986). In spite of its importance in communication, it is not easy to build a common ground. Hand crafting is too expensive. Machine learning is necessary but not sufficient, as it will not automatically create knowledge from the scratch. Under the current state of the art, human computing is considered to be a reasonable approach to break through the current limitation. To solicit high quality and spontaneous contribution from people, we need to make the process of common ground acquisition as playful as possible, by incorporating aspects of game, story and play. The notion of interaction game, named after Wittgenstein's language game, is critical to induce a strong engagement of participants.

Our research draws on conversational informatics which focuses on investigating human

behaviors and designing artifacts that can interact with people in a conversational fashion. The field draws on a foundation provided by artificial intelligence, natural language processing, speech and image processing, cognitive science, and conversation analysis. It aims to shed light on meaning creation and interpretation during conversation, in search of better methods of computer-mediated communication, human-computer interaction, and support for knowledge creation. We have been working on the idea since early 2000's and published the idea in 2007 from Wiley followed by AISB workshop in 2005.

The primary theoretical backbone is conversation quantization that integrates interaction and descriptive aspects of conversation. The conversation quantization is a theory to realize conversational intelligence based on the idea of conversation quanta. A conversation quantum represents an ideal observer's record of conversation. It packages relevant participants, references to the objects and events discussed in the discourse, a series of verbal and nonverbal utterances exchanged by the participants, commitments to previous discourse (themes), and new propositions in the discourse (rhemes). In the conceptual framework of conversational quanta, a conversation quantum takes a form of dictation from the observer's viewpoint or a script to be played in the forthcoming sessions of conversation. We assume that intelligent actors such as humans can both create a collection of conversational quanta on the fly while they are talking in conversation (materialization), and enable conversational interactions based on a collection of conversational quanta as a prototype (dematerialization). Memory processes will take and accumulate them into the structure of memory, as well as retrieve from the memory on demand. Long-term memory processes will intervene to generalize and reorganize accumulated conversational quanta. Some of them may be generalized and stored as a part of generic knowledge structure to be applied to broader discourses, while others may be indexed as a less interesting event in the episodic memory. Conversation itself is regarded as a part of a larger flow of conversational quanta in a collective dynamic memory process, just as Clark characterized conversation as a means for achieving a joint project.

Conversational informatics depends on four major techniques. The first is about conversational artifacts that can participate in conversations with people. The second is about conversational contents that can encapsulate information and knowledge arising in a conversational situation for reusing it in a new conversational situation. The third is about conversation environment design whose goal is to build a complete space that can provide participants with proper resources in conversation to enable smooth and effective interaction. The last technique is about conversation measurement, analysis, and modeling. We take a data-driven quantitative approach to understand conversational behaviors by measuring conversational behaviors using advanced sensing technologies and thereby aim at building detailed quantitative models of conversation.

Our research group has developed a rather comprehensive suite of techniques for conversational informatics ranging from analysis to application. Our approach has been based on sharing hypothesis: "the more is shared among the participants, the more empathy is gained." We have not tried to dive for the ultimate success—realization of a comprehensive artificial mind—from the beginning. Instead, we have been taking the state-of-the-art in conversational informatics as a basis and conducted an empirical approach by repeatedly increasing the common ground shared between humans and artificial agents. Among others, it involves multiple-sensor-based 3D conversation measurement and analysis suites for empirical study of social signal processing involving human-robot and even human-human interactions; immersive wizard-of-oz (WOZ) environment for human-robot interaction design and evaluation; cyber-physical conversation environment; learning-by-imitation as a data-intensive development of robot's competence of interaction; interactive joint intention formation as collaboration through conversation; simulated people as a means for investigating real-time collaboration between humans and robots.

Common ground has been one of the central issues in conversational informatics. Although the idea of co-evolution of common ground and conversational intelligence was introduced to boot-strap “the primordial soup of conversation” as a shared knowledge source for a conversational community of people and agents, its substantial implementation has not been conducted yet, due to the lack of a methodology.

## 2. Goal and Approach

The primary goal of this research is to establish a conceptual framework that can serve as a dependable theoretical basis for building a common ground. Toward this end, we build on conversational informatics, by addressing several technical aspects that we believe are critical to common ground building.

The first is learning by active imitation which allows robots to engage in interactions with people and other robots to share information, based on a collection of data obtained from human-agent interaction in the WOZ experiment. It implements the idea that the learning robot “watches” how people interact with each other, estimates how the target actor reacts according to the communicative behavior of the communication partner, and applies the acquired knowledge as estimated pat-terns of actions to the actual situations it encounters in conversation. So far, we have developed a suite of unsupervised learning algorithms for this framework. On top of the framework, we aim at adding autonomy and fluidity to our framework of learning by imitation. The major ideas are introduction of a top-down hierarchical feature and a developmental computational mechanism.

The second is estimation of the user’s mental status by integrating audio-visual cues and physiological indices. An ability to estimate the user’s emotion and stress is considered to be mandatory for building fellow agents that can build and sustain an almost equal relationship with the user by exploiting the common ground depending on the situation including the mental status of the user. A more complex method of estimation is needed in building a facilitator agent that can help a group of users to discuss in an effective and productive fashion. Dynamic nature of the user’s intention needs to be taken into account. Physiological indices may be used to obtain more reliable estimate in conducting experiments, while they may not be used in normal interactions.

The third is an integrated framework for interaction game design. We consider that technology-enhanced combination of dramatic role play and group discussions is promising, as the latter allows most people to participate in and contribute to the activity, the former permits each participant to reorganize knowledge from the viewpoint of a participating actor, while technology-enhancement is mandatory to make the group activity productive. To substantiate the idea, we have set out the conceptual framework of synthetic evidential study (SES), a novel technology-enhanced methodology that combines dramatic role play and group discussion to help people learn by spinning stories comprised of partial thoughts and evidence. We have completed an initial feasibility study on the effect of SES and figured out an architecture of an SES support system on the basis of conversational informatics. We believe that SES is a powerful and practical paradigm of human computing for building a common ground.

Our approach is highly empirical in nature regarding learning-by-imitation and estimation of mental status as well, though theoretical approach is needed to stabilize the basis and integrate the insights obtained from experiments.

## 3. Results

Major results encompass a robust learning algorithm from demonstration SAXImitate, an

integrated toolbox MC$^2$ (Motif Change and Causality Discovery), implementation and evaluation of a virtual basketball game, investigation of the effect of back imitation, a method for inducing intentional stance in HAI (Human-Agent Interaction), using physiological indices for discriminating intrinsic and extrinsic stress, and SES (Synthetic Evidential Study).

### 3.1 Learning from Demonstration for Acquiring Interaction Patterns

#### 3.1.1 Robust Learning from Demonstrations using Multidimensional SAX

We have developed a novel LfD (Learning from Demonstration) system based on a symbolization approach that utilizes the Symbolic Aggregate approXimation (SAX) timeseries symbolization algorithm after extending it to handle multi-dimensional time series found in LfD tasks. The proposed method, called SAXImitate, can be used as a stand-alone LfD system. SAXImitate is more resistant to confusing demonstrations that usually arise when action segmentation is automated. It can be used to cope with difficulties such as data scarcity, distortions, and confusions. Alternatively it can be used as a filtering step to provide better demonstration(s) for any other LfD system to take advantage of any superior encoding-utility of these systems that may be relevant to a specific LfD task.

This allows the proposed method to combine the advantage of being specially noise resistant with the advantages of other LfD systems. The proposed system is compared to representative implementations of two of the most widely used LfD systems, namely, Dynamic Motor Primitives (DMP) and probabilistic modeling exemplified by the Gaussian Mixture Modeling/Gaussian Mixture Regression (GMM/GMR) approach in learning basic motions from the CMU Mocap database as well as learning 2D drawings from demonstrations.

#### 3.1.2 Integrated Toolbox MC$^2$

To package tools into a suite, we developed an integrated toolbox MC$^2$ (Motif Change and Causality Discovery) that implements several state-of-the-art approaches to core problems in time-series analysis. MC$^2$ includes MD (Motif Discovery), CPD (Change Point Discovery), and CID (Causality Influence Discovery) for several applications in human behavior understanding, physiological signal processing, forecasting, analysis of climate data, cognitive modeling, etc. MC$^2$ implements multiple approaches to each of the three main problems of discovery in time-series and provides evaluation routines to compare the adequacy to different mining tasks. Showcase real-world applications include gesture discovery from accelerometer data and fluid imitation in human-robot interaction.

### 3.2 Cognitive Aspects of Interaction Game

#### 3.2.1 User Perceptions of Communicative and Task-competent Agents in a Virtual Basketball Game

We take the basketball game as a typical example of multi-player, real-time, situated game where collaboration and competence are deemed critical factors as well as physical performance. We are attempting at modeling the basketball game using Clark's joint activity theory. We characterize the top level of the basketball game as a collection of joint projects, including those for getting the ball into the opposition's hoop and stopping the other team from scoring. We model lower levels using the notion of joint projects for passing and catching the ball, or running certain plays. We are attempting at identifying various signals players use intentionally to communicate with each other. For example, a player may look towards a team-mate to indicate a pass, do a specific gesture indicating a certain play is to be executed, and so on. There are many situational gestures which may be executed at

various points in the game and ascribed meaning. While simple signals such as pointing are understandable to a majority of people, complex signals may be team-specific and therefore impossible for those not within the team to interpret. We are attempting to capture modalities players are using explicitly or implicitly to send signals. Verbal utterances may be used to direct players, though these are also received by members of the opposing team. As the basketball game is a fast-paced sport, complex strategies simply cannot be executed through utterances alone. Players may look towards non-verbal clues in order to determine the next course of action. These clues can be the state of the game itself (i.e., spatial positions of players on the court), or signals performed by players in the game. Players also use rich body expressions.

We prototyped as a research platform a virtual basketball game that will be played in a cyberspace by an ensemble of humans, avatars, and agents, when completed. We assume that the human players are familiar with the objective and rules of the basketball game. The user should be able to interact with their agent partners to create a situation of understanding and intuition which can be found in real-world sports teams. Each player in an immersive interaction environment is given the first-person or third-person with a tracking camera behind the user's avatar. We designed a virtual basketball game in which the users could control an avatar, perform basketball gestures and navigate the court without the need for hand-held peripherals. We incorporate into agents an ability to sustain proper social interactions with people. We extend the joint activity theory of H. Clark as a basis of designing and understanding interaction game.

We evaluated our joint activity theory-based agent model for the communication-competent agent. We assessed people’s perceptions of an agent team mate with higher basketball ability against one with higher communication ability. We found that people were able to distinguish between the two agents, and preferred the one with higher communication ability but there existed no difference in the perceived intelligence of the agents. This would suggest that users prefer communication ability to task ability in this environmental, though this could largely be due to the nature of the game itself.

#### 3.2.2 Effect of Back Imitation on Judgment of Imitative Skill

We have conducted three studies to explore the effects of imitating a robot (back imitation) on human’s perception of this robot in terms of imitative skill, interaction quality, humanness of the robot and intention of future interaction. The results of these studies taken together show that subjects preferred the robot that they previously imitated in terms of imitation skill, naturalness, and motion human-likeness compared with the robot that they did not imitate. There was no difference between the simple back imitation and the more complex mutual imitation conditions in the main study. This result supports the use of a back imitation familiarization session before learning form demonstration sessions. More generally, this result emphasizes the importance of taking the interaction context (and history) into consideration when attributing differences in people’s responses to robots.

#### 3.2.3 Induction of Intentional Stance in HAI by Presenting Goal-Oriented Behavior using Multimodal Information

The presence of fellow agents is critical for provoking the users’ serious engagement to make the human-agent interaction meaningful and productive, contributing to cultivating the common ground. We address conditions for motivating people to bear not only a positive feeling but also an intentional stance toward agents in the interaction game environment. In order to endow the agents with the ability of emotionally or/and intentionally interact with the user, we investigated cognitive aspects that may bring about enhancement of agents as a self-independent being.

We focused on “intentional stance”. Intentional stance is a mental state in which we think that an interaction partner has intention. We hypothesized that agents could induce the intentional stance by performing goal-oriented actions in human-agent interaction. To investigate the effect of induction of intentional stance, we made two agents: a “trial-and-error agent” that performed goal-oriented actions using multimodal behavior and a “text display agent” that displayed its behavioral intention via text. We conducted an experiment in which two participants played customized tag in virtual reality with one of the agents. The results showed that participants continuously tried to communicate with the trial-and-error agent, which did not respond to the participant’s actions except when necessary for performing the task. We found that the participants felt that the agent using multimodal nonverbal behavior was more goal-oriented, more intelligent and understood their intentions more than the agent that displayed text above its head. Thus, we were able to induce the intentional stance by presenting a trial-and-error process using multimodal behavior. We investigated a method for estimating the degree of concentration based on the physiological indices during VR exercise games. Also, in order to confirm whether or not the degree of users’ concentration keep by the advice at the timing based on the physiological indices, we controlled. As a result, in experimental group, the subjective degree of users’ concentration increased. In addition, the number of reaction of SCR decreased and of LF/HF increased. The results of the experiment suggest the possibility of inducing users to intended state by the advice at the timing based on the physiological indices.

#### 3.2.4 Using Physiological Indices for Discriminating Intrinsic and Extrinsic Stress

We used Immersive Collaborative Interaction Environment (ICIE), as it allowed participants to easily look around in the virtual space similar to the real world. The participant’s virtual avatar was intuitively controlled by their body motions using motion sensors placed on their dominant arm, both feet and waist. To determine the participant’s inner state, exercise quantity was estimated from the stepping motion and SCR and LF/HF were recorded by a device for measuring the physiological indices. This information was sent to the game system in real time. To distinguish intrinsic and extrinsic stress, the numbers of SCR and LF/HF responses were counted.

We developed a method for discriminating whether the cause of changes in a human’s activities are intrinsic factors related to spontaneous mental activities, or extrinsic stimuli generated by circumstances in continuous interaction, based on physiological indices and game context. A key to building an empathetic pedagogical agent to endow it an ability of estimating students’ inner states to evaluate the adequacy of an interaction agent’s behavior and the difficulty of the task set for the user.

We found that the SCR responses changed inversely with each other, with the difference in the experimental conditions being the inner state of the participant when the agent provided advice. This indicates that the effect of the advice differed depending on the inner state of the participant; and suggests that advice from the agent cannot create adequate learning effects without appropriate evaluation of a person’s inner state.

### 3.3 Synthetic Evidential Study—an Integrated Framework

Synthetic evidential study (SES for short) is a novel technology-enhanced methodology for combining theatrical role play and group discussion to help people spin stories by bringing together partial thoughts and evidences. SES combines theatrical role play and group discussion to help people spin stories by bringing together partial thoughts and evidences.

The SES framework consists of the SES sessions and the interpretation archives. In each SES session, participants repeat a cycle of a theatrical role play, its projection into an annotated agent play, and a group discussion. One or more successive execution of SES sessions until

participants come to a (temporary) satisfaction is called a SES workshop. In the theatrical role play phase, participants play respective roles to demonstrate their first-person interpretation in a virtual space. It allows them to interpret the given subject from the viewpoint of an assigned role. In the projection phase, an annotated agent play on a game engine is produced from the theatrical role play in the previous phase by applying the oral edit commands (if any) to theatrical actions by actors elicited from the all behaviors of actors. We employ annotated agent play for reuse, refinement, and extension in the later SES sessions. In the critical discussion phase, the participants or other audience share the third-person interpretation played by the actors for criticism. The actors revise the virtual play until they are satisfied. The understanding of the given theme will be progressively deepened by repeatedly looking at embodied interpretation from the first- and third- person views. The interpretation archive logistically supports the SES sessions. The annotated agent plays and stories resulting from SES workshops may be decomposed into components for later reuse so that participants in subsequent SES workshops can adapt previous annotated agent plays and stories to use as a part of the present annotated agent play.

SES leverages powerful game technologies to engage participants in a collaborative study on unveiling mysteries and other kinds of social processes by combining dramatic role play, agent play and group discussions to spin a story as a joint interpretation. It is evident that SES is a promising approach to build common ground in a cost-effective fashion. The SES support system is indispensable to make the SES methodology for everybody. Work is in progress to build the SES support system by combining technologies Nishida's group developed for conversational informatics research. It consists of an immersive interaction & collaboration environment for the shared virtual world, dramatic group play capture, creating agent play, discussion support, and conversation quantization. Learning by imitation and cognitive interaction design that Nishida's group is addressing will make the SES support system even more powerful. Potential application of SES is particularly useful in collaborative learning and authoring of interactive drama in storytelling that can be used in broad areas ranging from education and training to planning and simulation.

Prototyping an SES support system started in 2014, by incorporating a framework of interaction game, learning by imitation, and cognitive interaction design. We have extended the prototype of the SES support system built in the first year in several ways. First, we prototyped components for the SES users to exploit the interpretation archive to share and reuse annotations. Second, we introduced a light-weight tool for building the virtual space that may encompass virtual actors. Third, we developed a distributed shared environment for experimenting interactions as a virtual participant from the first person perspective.

We conducted a feasibility study with a partially implemented SES Support System. There were numerous encouraging results regarding the typical behavioral patterns of participants in role playing and how the inside understanding was deepened through the role play and discussion in the SES framework. We have conducted several experiments including incrementally accumulating interpretation of a passage of a novel "in the wood", a classic suspense story in which each character's intentions tangle in a complex fashion. Participants were asked to annotate scenes by adding comments of eight types: clarification, confirmation, empathy, conjecture, doubt, question, and surprise. The experiment consists of three stages. At the first stage, the participants had to start from no annotations, whereas at the second and third stages, they were allowed to refer to the annotations produced by predecessors. Annotations are structured as an interpretation network in terms of dependency between different stages.

To leverage the power of the SES framework in social interaction analysis and design, we prototyped a shared virtual space around a ticket office where avatars of participants of different roles are interacting with each other to play a role-specific behaviors, such as a counter person and a customer. We used this virtual setting to conduct a preliminary

experiment to compare the participants' comprehension of given social situations and preferred behaviors from the first- and third person view.

We have found that the SES framework effectively helped participants to formulate a coherent and consistent understanding of the given story by sharing articulated interpretations. According to the preliminary analysis we have obtained, the participants focused more on identifying facts and their relations by adding more confirmation-type annotations on the early stage of interpretation, while they added more conjecture-type annotations on the later phase. Based on correlation analysis, we obtained that correlation between conjecture and the depth of understanding measured by self-report in questionnaire is positive at the third stage. We also obtained from questionnaire analysis that none of the four participants reported that their opinion changed at the second stage, while all the five participants reported their opinion change at the third stage. It suggests that the participants started to build their interpretations by themselves. We suspect that questions and conjectures promote new conjecture. The more conjecture, the less questions. It may promote the deepening of interpretation and change of opinion. Furthermore, it is suggested that critical comments can be identified based on the degree centrality, i.e., the degree of a node, and critical comments are clustered in the interpretation network.

As a result from from a preliminary experiment with a shared virtual space around a ticket office, we have found that interpretation of the situation relies on the participant's viewpoint in a situation. The first person view seemed to induce stronger sense of engagement. We observed that the participants preferred a service counter with their cultural style to another with a different cultural style; they followed the social behaviors of their predecessors; and they preferred a fair service counter who rejects unreasonable line cutting.

**List of Publications and Significant Collaborations that resulted from your AOARD supported project:**

a) papers published in peer-reviewed journals,

1. Y. Mohammad and T. Nishida. Why Should We Imitate Robots? Effect of Back Imitation on Judgment of Imitative Skill. International Journal of Social Robotics, Published online, 2015.
   http://dx.doi.org/10.1007/s12369-015-0282-2
2. Yasser Mohammad, Toyoaki Nishida. Exact multi-length scale and mean invariant motif discovery. Applied Intelligence, Online First, 2015
   http://dx.doi.org/10.1007/s10489-015-0684-8

b) papers published in peer-reviewed conference proceedings,

1. 1. D. Lala, Y. Mohammad and T. Nishida. A joint activity theory analysis of body interactions in multiplayer virtual basketball, 28th British Human Computer Interaction Conference, Southport, UK, Sept. 9-12, 2014.
2. Y. Mohammad and T. Nishida. Robust Learning from Demonstrations using Multidimensional SAX, Proc. 14th International Conference on Control, Automation, and Systems (ICCAS 2014), KINTEX, Korea, October 22-25, 2014 (Outstanding Award).
3. D. Lala, C. Nitschke and T. Nishida. User perceptions of communicative and task-competent agents in a virtual basketball game. 7th International Conference on Agents and Artificial Intelligence (ICAART), Lisbon Portugal, 10-12 January 2015 (nominated as a candidate of best paper award).
4. T. Nishida et al. Synthetic Evidential Study as Augmented Collective Thought Process -- Preliminary Report, Accepted, 7th Asian Conference on Intelligent Information and Database Systems (ACIIDS 2015), Bali, Indonesia, 23-25 March, 2015.

in: N. T. Nguyen, B. Trawiński, R. Kosala (eds.) Intelligent Information and Database Systems, Lecture Notes in Computer Science Volume 9011, 2015, pp 13-22
http://link.springer.com/chapter/10.1007%2F978-3-319-15702-3_2

5. Takashi Ookaki, Masakazu Abe, Masahiro Yoshino, Yoshimasa Ohmoto, Toyoaki Nishida. Synthetic Evidential Study for Deepening Inside Their Heart. IEA/AIE 2015: 161-170, June 10-12, 2015
http://dx.doi.org/10.1007/978-3-319-19066-2_16
6. Yoshimasa Ohmoto, Seiji Takeda, Toyoaki Nishida. Distinction of Intrinsic and Extrinsic Stress in an Exercise Game by Combining Multiple Physiological Indices. VS-GAMES 2015:1-4, 16-18 Sept. 2015
http://dx.doi.org/10.1109/VS-GAMES.2015.7295770

c) papers published in non-peer-reviewed journals and conference proceedings,

1. T. Nishida et al. Synthetic Evidential Study as Primordial Soup of Conversation, Invited Guest Talk, DNIS 10th International Workshop on Databases in Networked Information Systems, University of Aizu, Japan, March 23 - 25, 2015
in: W. Chu, S. Kikuchi, and S. Bhalla (eds.) Databases in Networked Information Systems, Lecture Notes in Computer Science Volume 8999, 2015, pp 74-83
http://link.springer.com/chapter/10.1007%2F978-3-319-16313-0_6
2. Toyoaki Nishida. Conversational Informatics: Toward Cultivating Wisdom from Conversational Interaction, Keynote Speech. In: Proc. 19th Annual KES Conference, pp. 7–16, Singapore 7, 8 & 9 Sept. 2015.
http://dx.doi.org/10.1016/j.procs.2015.08.099

d) conference presentations without papers

1. Toyoaki Nishida. Bringing Conversational Informatics to Life, Keynote Talk, IEICE Sig VNV's Ten year anniversary meeting on March 28, 2015 (in Japanese).

e) manuscripts submitted but not yet published
None.

f) provide a list any interactions with industry or with Air Force Research Laboratory scientists or significant collaborations that resulted from this work.

1. A joint workshop with Prof. Il Hong Suh (Hanyang University): International workshop on robots and digital humans, Hanyang University, Seoul, Korea, December 13-15, 2015.

**Attachments:** Publications a), b) and c) listed above if possible.